



**Highly Absorbable
Magnesium**
New In Vitro Study Results

Chelamax®

Introduction

Selecting the right magnesium is vital for both consumers and manufacturers. The effectiveness of magnesium supplements depends on the structure of the magnesium and its reactivity in the gastrointestinal (GI) tract. Research shows that organically bound minerals, especially in chelated forms, are absorbed more effectively than inorganic minerals under similar conditions.^{1,2}

Innophos has recently conducted studies to confirm the superior absorption rates of its organically-bound, chelated magnesium products. In this paper, we outline a study that utilized an in vitro digestion model to verify that **Innophos magnesium products provide exceptional bioaccessibility and bioavailability.**

WHAT YOU WILL LEARN:

- Market drivers behind the **growing demand for magnesium**
- How to **overcome challenges of mineral absorption**
- **Increased absorption of Innophos magnesium** vs. magnesium oxide
- **Performance of Chelamax®** vs. Albion® Magnesium Bisglycinate

Consumer Demand for Magnesium

Magnesium, a vital mineral for the human body, plays a crucial role in numerous physiological functions. It is involved in over 300 enzymatic reactions, aiding in energy production, protein synthesis, cellular communication, bone health, and more. Magnesium contributes to a healthy lifestyle by promoting stress reduction, improved sleep quality, and enhanced cognitive function.

Only 40% of adults in the United States consume the recommended daily allowance (RDA) of magnesium.³

The RDA is approximately 420 mg for men and 320 mg for women, but the average diet in the U.S. and Europe only provides about 100 mg of magnesium, resulting in a 200-300 mg daily deficiency.⁴ Understanding of this deficiency, and the many benefits of magnesium, is driving consumer demand, **leading to one of the highest growth rates in the dietary supplement industry.**

Challenges of Mineral Absorption

When inorganic mineral oxides, such as magnesium oxide, dissociate in the stomach, undesirable reactions can occur, reducing mineral absorption. In contrast, organically bound minerals exhibit higher absorption rates. Binding the mineral to an organic ligand enhances its stability, allowing it to pass through the stomach and be easily absorbed in the small intestine.

THIS BINDING CAN OCCUR IN TWO WAYS:

1. Through a single-bond ligand, such as **glycerophosphate**
2. **Through full chelation**, which is when a ligand binds to the mineral in two locations



**Magnesium sales growth:
Over 50%
CAGR
since 2021⁵**

Innophos Magnesium Absorption Study

In Vitro Absorption Model

ProDigest®, a respected Contract Research Organization, used Simulator of the Human Intestinal Microbial Ecosystem (SHIME®) technology to test the bioaccessibility and bioavailability of Innophos chelated magnesium. This in vitro testing technology simulates the GI tract to mimic the process of human digestion and mineral absorption. The absorption is measured as magnesium passes through a dialysis membrane with a cut off of 14kDa, while the system controls pH, salt concentration, residence times, in vitro correlated volumes, enzyme concentrations, and bile salt concentrations. This system was validated for bioaccessibility and bioavailability and meets the INFOGEST 2.0 method guidelines.

Innophos' Chelamax® Magnesium Citrate, Chelamax® Magnesium Bisglycinate, and Magnesium Glycerophosphate were evaluated in the study. These compounds were all made into capsules targeting a total dosage of 83.5 mg of magnesium in a single "00" sized capsule. A commercially available tablet of 500 mg magnesium oxide dosage was used as an inorganic control. While the concentration in magnesium oxide is much greater, the overall absorption is expected to be much lower, showing the value of organically bound magnesium in improved absorption.

BIOACCESSIBLE

the QUANTITY of a compound that is AVAILABLE FOR ABSORPTION

(in supplements it is solubility in the GI tract)

VS

BIOAVAILABLE

the FRACTION of the compound that is ACTUALLY ABSORBED

(influenced by food eaten, bioaccessibility, individual metabolism, concentration in the body i.e. deficiency)

Results: Bioaccessibility in the GI tract

The bioaccessibility of a compound is defined as the quantity of that compound that is available for absorption. In supplements, it is related to the solubility of the compound in the GI tract. The bioaccessibility of each magnesium compound was measured after completion of the gastric and duodenal phases of the small intestine.

As shown in Figure 1, all tested compounds were soluble except for the magnesium oxide sample, which had very poor solubility. **Chelamax® Magnesium Bisglycinate had the highest percentage of soluble magnesium.**

BIOACCESSIBILITY COMPARISON OF MAGNESIUM SAMPLES

After 45 minutes digestion and 27 minutes in the duodenal phase

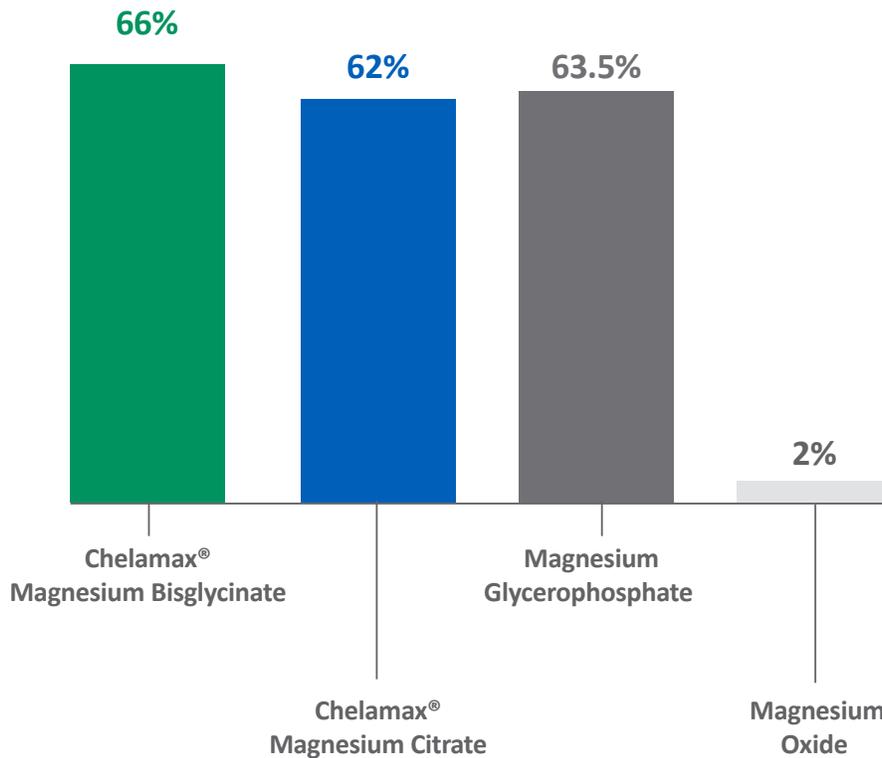


Figure 1. Magnesium oxide is poorly bioaccessible while the organically bound products remain soluble. The improved solubility allows for greater bioaccessibility in the small intestine where absorption occurs.



Results: Bioavailability in the GI tract

Bioavailability refers to the fraction of the compound that is absorbed in the GI tract. As shown in Figure 2, organically bound magnesium resulted in better absorption than the inorganic magnesium oxide salt under the same conditions. **More than 60% of Chelamax® Magnesium Bisglycinate was absorbed through the membrane which corresponded to over 90% of the bioaccessible magnesium.**

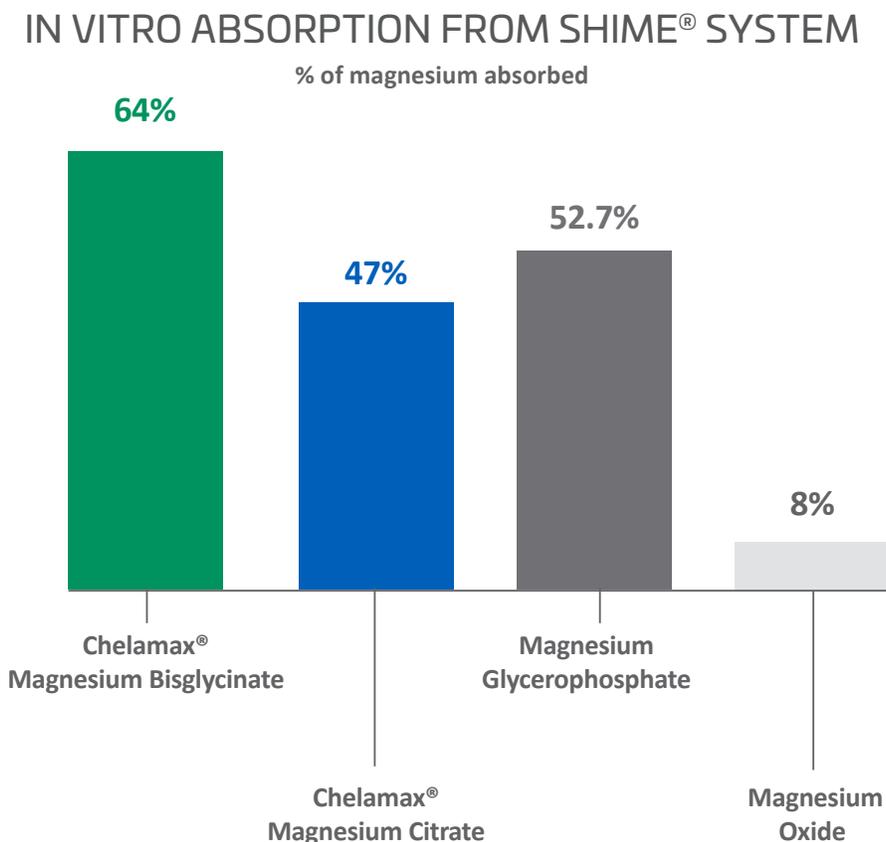


Figure 2. The percentage of magnesium absorbed by each sample in the ProDigest® SHIME® test system represents the final test point after 3h in the dialysis membrane.

The advantage of an organically bound magnesium is clear in Figures 1 and 2. Chelamax® Magnesium Bisglycinate, Chelamax® Magnesium Citrate, and Magnesium Glycerophosphate all show high absorption versus magnesium oxide. The poor bioaccessibility of magnesium oxide resulted in only 7.6% of the magnesium absorbed through the membrane.

Chelamax® organically bound compounds clearly outperform magnesium oxide in terms of final absorption. Despite using 500 mg of magnesium oxide compared to only 83.5 mg of chelated magnesium in this experiment, the **chelated compounds demonstrated 5 to 8 times higher absorption rates.** The choice of magnesium supplement is critical for maximizing absorption. Although magnesium oxide contains 60% magnesium, its poor solubility results in low absorption.

More than 60% of Chelamax® Magnesium Bisglycinate was absorbed through the membrane which corresponded to over 90% of the bioaccessible magnesium.

Chelamax[®] Magnesium Bisglycinate: A Superior Chelated Magnesium to Albion[®]

Not all chelated minerals perform equally, so we conducted a study to compare the absorption of Chelamax[®] Magnesium Bisglycinate to Albion[®] Magnesium Bisglycinate, a leading competitor. The goal of this study was to determine which product had greater absorption in side-by-side in vitro testing.

Similar to prior testing, both samples were prepared in capsules and formulated to contain 83.5 mg magnesium in a single capsule dose. The results, depicted below in Figure 3, demonstrate that **Chelamax[®] Magnesium Bisglycinate clearly outperformed Albion[®] Magnesium Bisglycinate. Chelamax[®] exhibited 35% higher absorption compared to Albion[®] at an equivalent dosage, highlighting its superior bioavailability as a chelated magnesium source.**

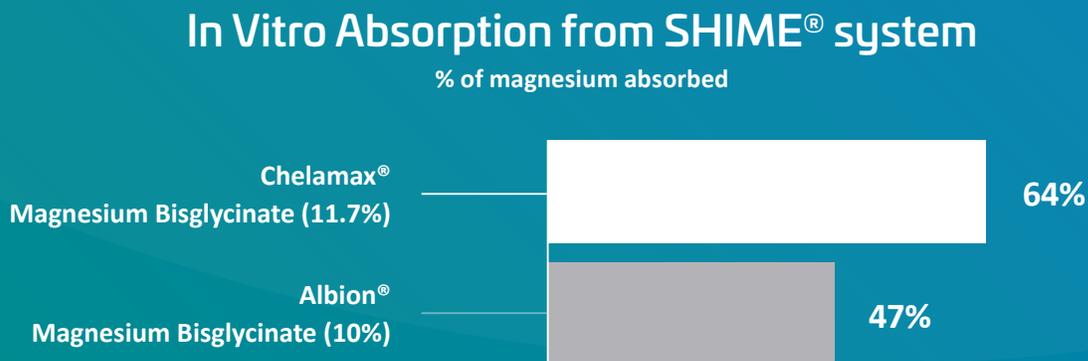


Figure 3. Comparison of Innophos Chelamax[®] Magnesium Bisglycinate versus Albion[®] Magnesium Bisglycinate using the SHIME[®] in vitro system.

Comparison of Absorption per Gram of Magnesium

	Chelamax[®]	ALBION[®]	% IMPROVEMENT when using Chelamax[®]
ABSORPTION (SHIME [®])	63.5%	46.7%	35%
Magnesium content per gram*	117 mg	100 mg	17%
Absorption per gram	74.3 mg	46.7 mg	59%

*Magnesium content based on the label descriptions of both products.

Figure 4. Comparison of absorption from SHIME[®] testing, normalized on a per gram of Magnesium Bisglycinate basis. The absorption percentage determined in SHIME was multiplied by the magnesium content for each compound, 11.7 % for Chelamax[®] and 10% for Albion[®]. This calculates the magnesium absorbed per gram from each compound.

The improvement in absorption of Chelamax[®] grows to 59% over Albion[®] when accounting for the difference in magnesium content.

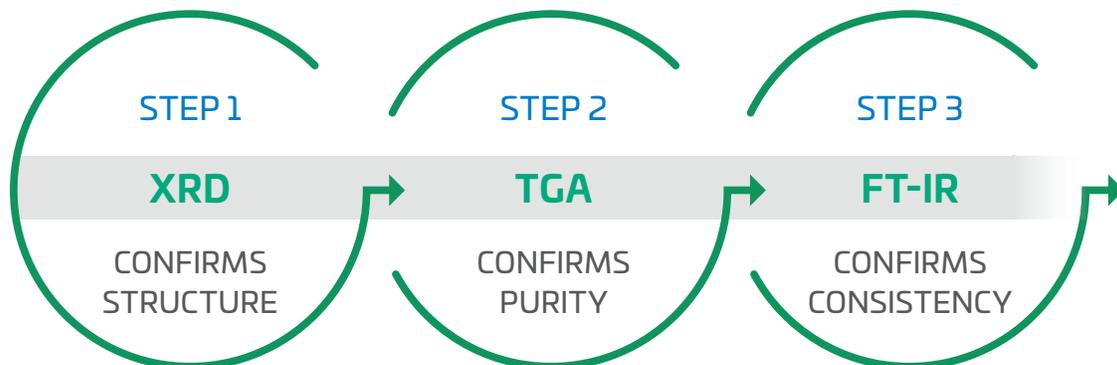
Which is the Best Magnesium Form for My Application?

Innophos' magnesium products are designed to meet the requirements of today's most consumed nutraceutical applications—capsules, tablets, and gummies.

MAGNESIUM FORM	CAPSULES	TABLETS	GUMMIES	DETAILS
Chelamax® Magnesium Bisglycinate High Density	✔		✔	This product can reach 120 mg magnesium in a standard "00" sized capsule while other commercially available products only contain 100 mg magnesium in a "000" larger capsule.
Chelamax® Magnesium Bisglycinate Magnesium Glycerophosphate		✔ ✔		These directly compressible products require fewer excipients to form non-friable tablets, making them particularly useful where the daily recommended intakes may push a single dose to several tablets.
Chelamax® Magnesium Citrate Fine Mesh			✔	Chelamax® Magnesium Citrate allows high levels with reduced grittiness, making it ideal for popular pectin-based gummy supplements. It can achieve 40 mg of magnesium per gram of gummy, achieving the complete RDA in about 10 g of gummy product.

INNOPHOS 3-STEP VERIFICATION

Not all organically bound minerals are chelated. At Innophos, we have developed the most advanced analytical testing in the industry with our three-step verification process. This ensures full chelation of all Chelamax® products.

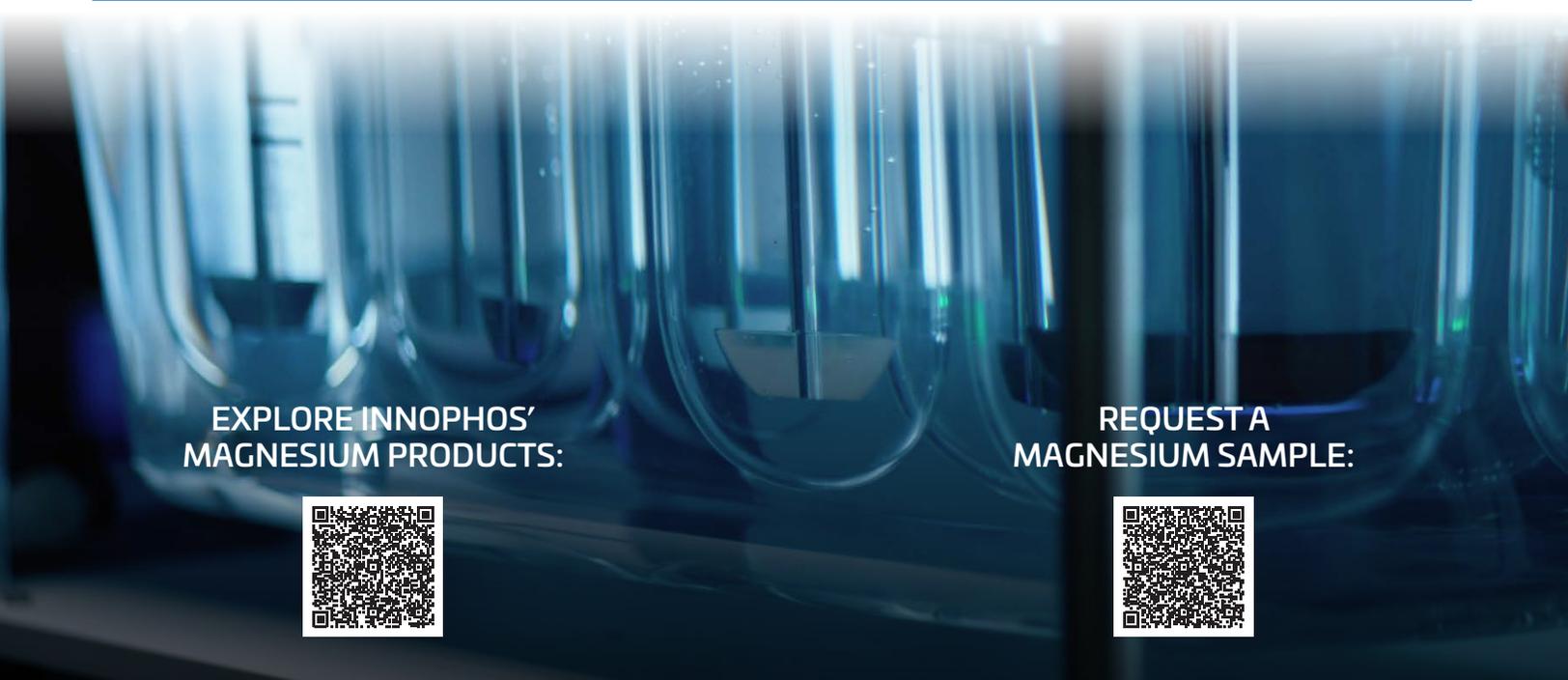


Conclusion

Innophos' rigorous research and development, including in vitro digestion model studies, confirm the superior bioaccessibility and bioavailability of Innophos' magnesium products. We offer three forms of magnesium, each designed for optimal absorption and tailored to different applications. Magnesium Bisglycinate, with the highest absorption rate, is ideal for tablets and capsules and is increasingly popular in gummies. Magnesium Citrate and Magnesium Glycerophosphate, which provide 5-8 times the absorption rate of magnesium oxide, are well-suited for gummies and tablets, respectively.

The critical factor is the amount of magnesium that consumers actually absorb from their supplements. As the demand for magnesium continues to surge, Innophos is committed to delivering the highest magnesium uptake across various forms, helping consumers effectively meet their daily requirements. By using Chelamax® in your supplement, consumers can trust that they are getting the most effective magnesium products available on the market.

**Innophos delivers science-backed,
highly absorbable magnesium for your supplements.**



**EXPLORE INNOPHOS'
MAGNESIUM PRODUCTS:**



**REQUEST A
MAGNESIUM SAMPLE:**



Author: Dr. Bob Finn, Director, R&D

References

- ¹ Schuette, S. A., Lashner, B. A., & Janghorbani, M. Bioavailability of magnesium diglycinate vs magnesium oxide in patients with ileal resection *1994 J. Par. Ent. Nutr.*, 18(5), 430-435.
- ² Walker, A.F., Marakis, G. Christic, S, and Byng M. Mg Citrate found more bioavailable than other Mg preparations in a randomized, double-blind study. *Magnesium research*, **2003**, 16(3)-tmr.world.com
- ³ <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3650510/#bib27>
- ⁴ <https://ods.od.nih.gov/factsheets/magnesium-healthprofessional/>
- ⁵ SPINS Natural Enhanced Channel and MULO, powered by Circana | -2021-2023
- ⁶ Fulgoni, V.L.; Keast, D.R.; Bailey, R.L.; Dwyer, J. Foods, Fortificants, and Supplements: Where Do Americans Get Their Nutrients? *J. Nutr.* **2011**, 141, 1847–1854.